<for Aug 2023>

EE4302 Advanced Control Systems/Sem I (4.0MCs)

Teaching Mode ---

Important note: The final exam will be conducted "in-person face-to-face", and thus the students taking this module will need to be physically present in Singapore.

Module Lecturers

- **Prof. T.H.Lee (eleleeth@nus.edu.sg)**
- **Prof. W.K.Ho (elehowk@nus.edu.sg)**

Relevant Basic Information

- **Very useful module for *EE4* students (and eligible Graduate Students) interested in state-variables and nonlinear systems. Especially useful for EE4 students currently working on FYPs in the Control Systems, Intelligent Systems, Robotics and Drives areas, and also Communications FYPs using ideas of state-variables (e.g. Kalman Filters). Also a very good module for interested *EE3* students, who are keen on taking up similar FYPs next year. [Note: About 25 EE3 students took EE4302 last year, and most of them went on to do such FYPs, and are doing very well!!] Strong foundation for careers in DSTA/DSO; Hewlett Packard Technology Divisions; National Instruments U.S.A.; Agilent U.S.A.; Emerson Electric; Yokogawa; automation companies; high-precision instruments companies (including biomedical); disk-drive companies; etc.**

- **Module Syllabus: Please see next page.**

- **Two CA assignments; CA Report grades will count towards continuous assessment (40 %).**

- **One exploratory mini-project-style CA; Mini-project Report grade will count towards continuous assessment (30 %).**

- **Examination grade will contribute the other 30%.**

EE4302 Advanced Control Systems (4.0MCs)

Pre-Requisites: **EE2010 Systems and Control**
Co-Requisites: **NIL**

Overview:

System description. Controllability; Selection of pole locations for good design. Observer design; observability; full-order and reduced-order observers. Combined control law and observer. Introduction of reference input. Non-linearities: non-linearities in control systems, use of root-locus in analysis of non-linear systems. Describing functions, use of describing functions in analysis and design of control systems, non-linear ordinary differential equations, singular points, phase plane analysis.

Aims of subject:

In this the subject, students learn about the state-variable approach to control systems analysis and design, and also about nonlinearities in control systems. This enables students to understand modern methods in control systems analysis and design which is useful for them in careers in control systems engineering and in further studies (or research) in this field.

Detailed Syllabus

(Time allocations are approximate. Adjustments will be made depending on needs of class.)

System Description I (1 hr)
- Introduction to state variables
- Conceptual analog module equations

System Description II (2 hr)
- State transformations
- System transfer functions
- Poles, zeros and eigenvalues

Controllability I (2 hr)
- State feedback
- Controllability as a concept

Controllability II (2 hr)
- Controller design
- Selection of Pole Location for Good Design

Observability I (2 hr)
- State observation
- Observability as a concept

Observability II (2 hr)
- Full order observers
- Reduced-order observers

Combined Compensator Design I (2 hr)
- Combined control law and observer
- Kalman separation principle

Combined Compensator Design II (2 hr)
- Relating state-variable and transform methods

Reference Inputs (1 hr)
- Scaling gains
- Integral control action

Introduction to non-linear control (1 hr)
- Why study nonlinear system
- Differences between linear and nonlinear systems

Root locus analysis of non-linear system (2 hr)
- nonlinearity with no dynamics
- nonlinearity that is well approximated as a gain that varies as the size of its input
- sketching of the root locus

Phase plane analysis (2 hr)
- equilibrium points
- constructing the phase portrait: analytical method, method of isoclines
- determining time from phase portraits

Describing function analysis (3 hr)
- application areas
- computing describing functions: analytical calculation, numerical integration, experimental evaluation
- describing functions of common nonlinearities: saturation, relay, dead-zone, backlash
- existence of limit cycle
- stability of limit cycles

Controller design (2 hr)
- design of PID controllers using describing function of relay
- gain scheduling

Text Books

1) G F Franklin, J D Powell and A Emami-Naeini, “Feedback Control of Dynamic Systems”, 3rd Edition, Prentice-Hall, 1995; or 4th Edition, Prentice-Hall, 2002.
2) J J Slotine and W Li, “Applied Nonlinear Control,” Prentice-Hall, 1991.

Reference Books

1) T Kailath, “Linear Systems”, Prentice-Hall, 1980
2) B Friedland, “Control System Design”, McGraw-Hill, 1987